MIXOR (version 2): a program for 2-level cumulative link models

Some enhancements, extensions, and examples

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email: hedeker@uic.edu
url: http://www.uic.edu/~hedeker/mix.html
Notation:

- $i = 1 \ldots N$ level-2 units
- $j = 1 \ldots n_i$ level-1 units for level-2 unit $i$
- $c = 1 \ldots C$ categories for response variable $v_{ij}$

The response model for MIXOR2 can be written as:

$$ z_{ijc} = \gamma_c \pm \left[ u'_{ij} \zeta_c + w'_{ij} \alpha + x'_{ij} \beta_i \right] $$

with $\gamma_1 = 0$, $\zeta_1 = 0$, and $\beta_i \sim N(\mu, \Sigma)$, or by standardizing the random effects as

$$ z_{ijc} = \gamma_c \pm \left[ u'_{ij} \zeta_c + w'_{ij} \alpha + x'_{ij} \mu + x'_{ij} \theta_i \right] $$

with $\theta_i \sim N(0, I)$ and $\Sigma = TT'$

- $x = R$ variables for the random effects
- $w = P$ explanatory variables
- $u = h$ variables (a subset of the $P$ explanatory variables) that interact with the $C-2$ thresholds $(\gamma_2, \ldots, \gamma_{C-1})$

$\Rightarrow$ for each of the $h$ variables in both $w$ and $u$:

- $\alpha$ includes the effect on the first threshold
- $\zeta_c$ includes $C-2$ deviations from the effect on the first threshold

**New Features**

- $\pm$ (+ used by SAS PROC LOGISTIC and for survival models)
- $\zeta_c$ non-proportional odds (for the logistic response function, and the analogous generalization under the normal, log-log, and complementary log-log response functions) for explanatory variables $u$
- Response functions allowed (for $c = 1 \ldots C-1$)

$$ P(v_{ij} \leq c) = \begin{cases} 
\Phi(z) & \text{normal} \\
\Psi(z) & \text{logistic } 1/(1 + \exp(-z)) \\
\Upsilon(z) & \text{clog-log } 1 - \exp(-\exp(z)) \\
1 - \Upsilon(z) & \text{log-log } \exp(-\exp(z)) 
\end{cases} $$
• Structure of random effect(s)

\[
T = \begin{cases} 
\vdots & \text{correlated random effects} \\
\cdot & \text{independent random effects} \\
\vdots & \text{varying } \sigma^2_{\beta} \text{ across } j \text{ or groups of } i
\end{cases}
\]

The latter option is useful for:

- separate \( \sigma^2_{\beta} \) for groups of level-2 units (e.g., DZ and MZ twins)

- separate \( \sigma^2_{\beta} \) for distinct level-1 units (e.g., test items within subjects)

• Mean (vector) of random effects \( \mu \) is estimated or set equal to 0

• Allows right censoring of the ordinal response \( v_{ij} \)

  - for 2-level grouped-time survival analysis
    - only know \( v_{ij} > c \)
    - \( P(v_{ij} > c) = 1 - P(v_{ij} \leq c) \)
    - note: right-censoring for last category \( C \) is akin to adding category \( C + 1 \)
    - can estimate \( \gamma_C \) and \( \zeta_C \)

• Provides linear transformations of estimated parameters and standard errors

  - \( \alpha_1 + \alpha_2 \)
  - \( \alpha_1 + \zeta_1 \)

• Produces additional output files

**MIXOR.EST** - a file containing the estimated parameters (with labels).

**MIXOR.VAR** - a file containing the large-sample variance covariance matrix of the parameter estimates (the inverse of the information matrix). The full rectangular matrix is printed out, row by row, with the order of the parameters identical to that of MIXOR.EST (i.e., no labels are given in MIXOR.VAR).

**MIXOR.RES** - if there is only one random effect (either \( R=1 \), or \( R>1 \) and VGRP=1, see below) then a file containing empirical Bayes estimates of the random effect for each level-2 unit is produced. This file lists for each level-2 unit: level-2 ID, the number of level-1 units \( n_i \), the empirical Bayes estimate (posterior mean), and the posterior standard deviation. Additionally, if each level-2 unit has a frequency weight, then this weight is also output to this file immediately following the level-2 ID (and before \( n_i \)).
Mixed-effects Partial Proportional Odds Model


To illustrate this feature, we’ve used published data that represent ordinal responses from subjects on three items concerning attitudes towards sex. Item responses (level-1) are nested within subjects (level-2).

DATASET: NORCAG.DAT
FIELDS: 1 PATTERN ID
2 ORDINAL ITEM RESPONSE (1 to 4)
3 INTERCEPT
4 ITEM 2 vs ITEM 1 (dummy-coded variable)
5 ITEM 3 vs ITEM 1 (dummy-coded variable)
6 FREQUENCY WEIGHT OF PATTERN

DEF FILES: NORCAG.DEF
random intercepts model assuming proportional odds for differences in item responses
NORCAG2.DEF
random intercepts model allowing non-proportional odds for differences in item responses

(this article lists the data found in NORCAG.DAT)
Data from Agresti & Lang (1993)

Opinions on teenage, premarital, and extramarital sex
1989 General Social Survey

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1 = always wrong, 2 = almost always wrong
3 = wrong only sometimes, 4 = not wrong.
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Proportional Odds Model - MIXOR setup

**Title 1:** NORC data 3 ordinal items - Agresti & Lang (93) Biometrika

**Title 2:** Random intercept proportional odds model

- **Definition File Name:** c:\rm99\norcag.def
- **Input File Name:** norcag.DAT
- **Output File Name:** norcag.OUT

- **Number of Data Fields:** 6
- **Convergence Criterion:** 0.0001
- **Level-2 Units to List:** 1
- **Field for Level-2 Units:** 1
- **Unit Weighting:** differential
- **Field for Assigned Weight:** 6
- **Function Model:** logistic
- **Number of Quadrature Points:** 10
- **Prior Distribution:** specific
- **Prior for Numerical Quadrature:** normal

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

---

**Ordinal Outcome Variable Field:** 2

**Ordinal Outcome Var. Label:** SexItems

**Ordinal Outcome Variable Categories:** 4

**Number of Random Effects:** 1

**Random Effect** | **Field** | **Label**
---|---|---
1 | 3 | Intercept

**Number of Explanatory Var. Effects:** 3

**Expl. Var. Effect** | **Field** | **Label**
---|---|---
1 | 3 | Intercept
2 | 4 | Item2vs1
3 | 5 | Item3vs1

**Perform Crosstabulation:** no

Enter the field of the input file which contains the dichotomous or ordinal outcome variable.
Mixed-effects Grouped-Time Survival Analysis Model


The data represent smoking experimentation onset in a sample of seventh grade students measured at four timepoints (baseline, post-intervention, 1 year follow-up, and 2 year follow-up). Students (level-1) are nested within classrooms (level-2) and schools (level-3). Since MIXOR can only currently handle two-level data, the example analyses consider students within classrooms. CC and TV are school-level intervention variables. Sex is a student-level variable.

DATASET: SMKCCLC.DAT
FIELDS: 1 SCHOOL ID
2 CLASS ID
3 SUBJECT ID
4 SMOKING EVENT/CENSOR TIME INTERVAL (1 to 4)
5 SMOKING EVENT/CENSOR INDICATOR (0=CENSOR 1=EVENT)
6 INTERCEPT
7 SEX (0=f 1=m)
8 CC INTERVENTION CONDITION (0=no 1=yes)
9 TV INTERVENTION CONDITION (0=no 1=yes)
10 CC × TV

DEF FILES: SMC05A.DEF
proportional hazards model ignoring data clustering
(yields same results as SAS PROC PHREG with TIES=EXACT option)
SMC15A.DEF
proportional hazards model with a random classroom effect
SMC15C.DEF
partial proportional hazards model with a random classroom effect;
the effect of SEX is allowed to vary across the grouped-time intervals

DATA FROM: Flay, B. et. al. (1988).
The Television School and Family Smoking Prevention and Cessation Project: I. Theoretical basis and program development.
Preventive Medicine, 17, 585-607.
(This article describes the dataset).
**ASCII file - SMKCCLC.DAT**

Fields: school ID, class ID, subject ID, smoking onset, censor/event (0=censor, 1=event), intercept, sexmale, CC, TV, CC × TV

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</table>
Survival Model: Gender effect varies across time - MIXOR setup

**Title 1:** TVSFP Onset of SMOKING (Waves B through D) Survival Analysis

**Title 2:** Random and 5 fixed effects - VARYING THRESHOLDS BY SEX

- **Definition File Name:** c:\rm99\smc15c.def
- **Input File Name:** smkColr.dat
- **Output File Name:** smc15C.out

- **Number of Data Fields:** 10
- **Convergence Criterion:** 0.000010
- **Level-2 Units to List:** 1
- **Field for Level-2 Units:** 2
- **Unit Weighing:** equal
- **Function Model:** comp. log-log
- **Number of Quadrature Points:** 20
- **Prior Distribution:** specific
- **Prior for Numerical Quadrature:** normal

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

**Ordinal Outcome Variable Field:** 4

**Ordinal Outcome Var. Label:** SmkOnset

**Ordinal Outcome Variable Categories:** 3

**Number of Random Effects:** 1

<table>
<thead>
<tr>
<th>Random Effect</th>
<th>Field</th>
<th>Label</th>
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<tbody>
<tr>
<td>1</td>
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<td>Interpt</td>
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</tbody>
</table>

**Number of Explanatory Var. Effects:** 5

<table>
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<th>Expl. Var. Effect</th>
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<tr>
<td>2</td>
<td>6</td>
<td>Interpt</td>
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<tr>
<td>3</td>
<td>8</td>
<td>CC</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>TV</td>
</tr>
</tbody>
</table>
Mixed-effects Probit Model with Varying Level-2 Variance by Level-2 Grouping Variable

The data represent responses from twins on a dichotomous TROUBLE CONCENTRATING outcome. Each twin sibling (level-1) is nested within the twin pair (level-2). Twin pairs are either monozygotic or dizygotic.

**DATASET:** CONCEN.DAT

**FIELDS:**

1. PATTERN ID
2. TROUBLE CONCENTRATING (0=absent 1=present)
3. INTERCEPT
4. MZ TWIN INDICATOR VARIABLE (1=MZ 0=DZ)
5. DZ TWIN INDICATOR VARIABLE (1=DZ 0=MZ)
6. FREQUENCY WEIGHT OF PATTERN

**DEF FILES:** CONCEN.DEF

- random intercepts model assuming the same intraclass correlation for both twin pair types (MZ and DZ)

CONCEN2.DEF

- random intercepts model assuming different intraclass correlations for twin pair types (MZ and DZ)

**DATA FROM:** Ramakrishnan, V., et. al. (1992).
Elementary methods for the analysis of dichotomous outcomes in unselected samples of twins.
Genetic Epidemiology, 9, 273-287.
(this article lists the data found in CONCEN.DAT)
Data from Ramakrishnan et al. (1992) *Genetic Epidemiology*

Twin Data - Analysis of Trouble Concentrating
Observed Frequencies

<table>
<thead>
<tr>
<th>Zygosity</th>
<th>Trouble Concentrating Twin 1</th>
<th>Trouble Concentrating Twin 2</th>
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</thead>
<tbody>
<tr>
<td>Present</td>
<td>1275</td>
<td>323</td>
</tr>
<tr>
<td>Absent</td>
<td>310</td>
<td>203</td>
</tr>
</tbody>
</table>

*odds ratio = 2.6 and tetrachoric correlation = .33*

<table>
<thead>
<tr>
<th>Zygosity</th>
<th>Trouble Concentrating Twin 1</th>
<th>Trouble Concentrating Twin 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>964</td>
<td>285</td>
</tr>
<tr>
<td>Absent</td>
<td>303</td>
<td>153</td>
</tr>
</tbody>
</table>

*odds ratio = 1.7 and tetrachoric correlation = .19*
ASCII file - CONCEN.DAT

Fields: pattern ID, response, intercept, MZ indicator, DZ indicator, pattern frequency

```
  11 0 1 1 0  203
  11 0 1 1 0  203
  21 1 1 1 0  310
  21 0 1 1 0  310
  31 0 1 1 0  323
  31 1 1 1 0  323
  41 1 1 1 0 1275
  41 1 1 1 0 1275
  10 0 1 0 1  153
  10 0 1 0 1  153
  20 1 1 0 1  303
  20 0 1 0 1  303
  30 0 1 0 1  285
  30 1 1 0 1  285
  40 1 1 0 1  964
  40 1 1 0 1  964
```
Probit model with common tetrachoric correlation - MIXOR setup

Title 1: MZ & DZ twins - Trouble Concentrating - Ramakrishnan (1992)
Title 2: Common ICC - model with MZ
Definition File Name: c:\rm99\concen.def
Input File Name: CONCEN.DAT
Output File Name: CONCEN.out
Number of Data Fields: 6
Convergence Criterion: 0.00010
Level-2 Units to List: 1
Field for Level-2 Units: 1
Unit Weighting: differential
Field for Assigned Weight: 6
Function Model: probit
Number of Quadrature Points: 20
Prior Distribution: specific
Prior for Numerical Quadrature: normal

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

Ordinal Outcome Variable Field: 2
Ordinal Outcome Var. Label: TConcen
Ordinal Outcome Variable Categories: 2

Number of Random Effects: 1
Random Effect Field Label
1 3 Intercept

Number of Explanatory Var. Effects: 2
Expl. Var. Effect Field Label
1 3 Intercept
2 4 Mz

Perform Crosstabulation: no

Enter the field of the input file which contains the dichotomous or ordinal outcome variable.
Starting Values: automatic

Missing Values Present: false

Right-Censoring: none

Model Terms: subtract

Random Effect Mean Vector: fix to 0

Transforms to Estimate: 0

Select between no right-censoring and including right-censoring.
Probit model with varying tetrachoric correlation - MIXOR setup
Starting Values: automatic

Missing Values Present: false

Right-Censoring: none

Model Terms: subtract

Random Effect Mean Vector: fix to 0

Random Effects Grouping: yes

Transforms to Estimate: 0

Specify 'yes' only if the 2 random effects variables are dummy-coded level-1 or level-2 grouping variables; otherwise specify 'no'.
2-parameter Item Response Theory (IRT) Model as a Mixed-effects Logistic Model with Varying Level-2 Variance (i.e. the effect of subject’s ability) by Level-1 “Grouping” Variable (i.e., the item)

The data represent four item responses from subjects. Each item (level-1) is nested within subjects (level-2). The subject’s sex (level-2) is also given.

**DATASET:** ASVABEX.DAT

**FIELDS:**
1. PATTERN ID
2. ITEM RESPONSE (0=incorrect 1=correct)
3. INTERCEPT
4. ITEM 1 INDICATOR VARIABLE (0=no 1=yes)
5. ITEM 2 INDICATOR VARIABLE (0=no 1=yes)
6. ITEM 3 INDICATOR VARIABLE (0=no 1=yes)
7. ITEM 4 INDICATOR VARIABLE (0=no 1=yes)
8. SEX (0=male 1=female)
9. SEX × ITEM 1
10. SEX × ITEM 2
11. SEX × ITEM 3
12. SEX × ITEM 4
13. FREQUENCY WEIGHT OF PATTERN

**DEF FILES:**
- ASVMODA.DEF
  2-parameter logistic item response theory (irt) model
- ASVMODB.DEF
  2-parameter model including an overall SEX effect
- ASVMODC.DEF
  2-parameter model including a separate SEX effect on each item intercept
- ASVMODD.DEF
  2-parameter model including a separate SEX effect on each item intercept plus an overall SEX effect on the item slopes
- ASVMODE.DEF
  2-parameter model including a separate SEX effect on each item intercept plus a separate SEX effect on each item slope

**DATA FROM:** Mislevy, R.J. (1985)
Estimation of latent group effects.
(this article lists the data found in ASVABEX.DAT)
Data from Mislevy (1985)

Armed Services Vocational Aptitude Battery
ASVAB arithmetic reasoning items: white males & females
Counts of Observed Response Patterns

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<th>20</th>
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<td>14</td>
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<tr>
<td>0 1 0 0</td>
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<td>20</td>
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<tr>
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<td>0 1 0 1</td>
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<td>5</td>
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| total         | 263 | 228 |
ASCII file - ASVABEX.DAT

Fields: pattern ID, response, intercept, Item1-Item4, SexF, SexF by Item1 to SexF by Item4, pattern frequency

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1 0 1 0 1 0 0 0 0 0 0 0 23
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1 0 1 0 0 0 1 0 0 0 0 0 23
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9 0 1 0 0 1 0 0 0 0 0 0 5
9 1 1 0 0 0 1 0 0 0 0 0 5
5 0 1 1 0 0 0 0 0 0 0 0 12
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4 0 1 0 0 0 1 1 0 0 0 1 18
12 1 1 1 0 0 0 1 1 0 0 0 15
12 1 1 0 1 0 0 1 0 1 0 0 15
12 0 1 0 0 1 0 1 0 0 1 0 15
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8 0 1 0 0 0 1 1 0 0 0 1 20
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16 1 1 0 1 0 0 1 0 1 0 0 42
16 1 1 0 0 1 0 1 0 0 1 0 42
16 1 1 0 0 0 1 1 0 0 0 1 42
```

2-parameter IRT model - MIXOR setup

Title 1: ASVAB Data - 4 items - aggregated data
Title 2: 2 parameter logistic - Model A
Definition File Name: c:\rrm99\asvmoda.def
Input File Name: ASVABex.DAT
Output File Name: ASVMODA.OUT
Number of Data Fields: 13
Convergence Criterion: 0.0001
Level-2 Units to List: 1
Field for Level-2 Units: 1
Unit Weighting: differential
Field for Assigned Weight: 13
Function Model: logistic
Number of Quadrature Points: 20
Prior Distribution: specific
Prior for Numerical Quadrature: normal

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

Ordinal Outcome Variable Field: 2
Ordinal Outcome Var. Label: ASVAB88a
Ordinal Outcome Variable Categories: 2

Category | Value
--- | ---
1 | 0
2 | 1

Number of Random Effects: 4
Number of Explanatory Var. Effects: 0

Perform Crosstabulation: no

Enter the field of the input file which contains the dichotomous or ordinal outcome variable.
2-parameter IRT model: Gender-varying intercepts - MIXOR setup

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

Enter the field of the input file which contains the dichotomous or ordinal outcome variable.
2-parm IRT: Gender-varying intercepts & slopes - MIXOR setup

Enter the main title for the data. The maximum length is 60 characters. Titles which exceed 60 characters are automatically clipped to the maximum length.

Enter the field of the input file which contains the dichotomous or ordinal outcome variable.